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Species composition, distribution and management of trees in rice paddy fields in central Lao, PDR

Y. Kosaka[1,*], S. Takeda[1], S. Prixar[2], S. Sithirajvongsa[2] and K. Xaydala[2]
*[1]Graduate School of Asian and African Area Studies, Kyoto University, Kyoto, 606-8501 Japan; [2]Faculty of Forestry, National University of Laos, Vientiane, Lao PDR; *Author for correspondence (e-mail: kosaka@asafas.kyoto-u.ac.jp; phone: +81-75-753-7839; fax: +81-75-753-7834)*

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Abstract

Presence of different types of trees dispersed singly or in small groups throughout the fields is a very common feature in the extensive rice paddies of Laos and Thailand. Factors such as land-settlement history, proximity to forest, and role of species in the local culture are known to influence the nature and distribution of tree species so retained. The extent of influence of these factors on tree-species composition and distribution in rice paddies was investigated in three villages in Central Laos: Dongmakngeo, a newly established village with an abundance of adjacent forest; Bak, an old village with adjacent forest; and Nakhou, an old village without any adjacent forest. At Dongmakngeo village, 23 species, mostly remnants from the original forest, were observed in paddy fields. At Bak village, few trees were found in the paddy fields because villagers had ample access to resources in the surrounding large forest. On the other hand, 119 species, 27 of which were planted, were recorded at the forest-deprived Nakhou village; the scarcity of forest resources at Nakhou was compensated for by the utilization and management of trees located among the fields, resulting in tree species changing from remnant to ruderal over time. Thus, our results demonstrate that the pattern of tree distribution and species composition in paddy landscapes is not uniform, but varies in relation to settlement history, topography, and human management. This has important implications for setting both landscape-level land-use management plans and local tree management policies for achieving sustainable tropical paddy-dominated agro-silvicultural systems.

Introduction

The role of trees in tropical agricultural landscapes has been studied from various perspectives, such as the improvement of productivity and sustainability (e.g. Kwesiga et al. 2003), subsistence and food security (e.g. Wezel et al. 2003), and conservation of biodiversity (e.g. Harvey and Haber 1999). The presence or absence of trees has also been shown to sometimes play a role in securing or maintaining rights of use or tenure, and certain trees or wooded areas can be of cultural or religious importance (Arnold 1995). Analyses of the tree component of agricultural landscapes with these types of narrowly focused perspectives are unlikely to provide a satisfactory picture of why farmers do or do not grow trees unless there is recognition of the broader framework within which the farm trees are located (Arnold 1995). Consequently, research interest has switched to a more holistic and dynamic approach.

The paddy field land-use system is dominant in tropical Asia. Importantly, it is also the principal alternative land-use where shifting cultivation is being phased out (e.g. Lao PDR RD Program 1998). Throughout central Laos and northeast Thailand, widespread undulating plains display a distinctive landscape of trees standing singly or in small groups amongst a mosaic of rain-fed paddy fields, levees, and residential plots or clusters. Previous studies have shown that trees in the paddy landscape supply wood, food, medicine and other supplementary resources, offer shade to both humans and livestock (Grandstaff et al. 1986; Watanabe et al. 1990; Prachaiyo 2000), mitigate land degradation (Vityakon 1993; Vityakon 2001), and provide habitat for wildlife (Grandstaff et al. 1986).

Despite the wide range of uses for trees in the paddy landscape in central Laos and Thailand, the species composition and distribution of trees differs from place to place. Some fields have a high density of forest species while others have little more than a sparse distribution of planted species; some fields have no trees at all. Prachaiyo (2000) reported that species composition in northeast Thailand is dependent on major topographic variations and soil type. Other factors also appear to be important. For example, tree distribution and growth seems to vary with micro topography or time since conversion from forest to paddy field. In addition, the extent to which local people utilize trees within the surrounding environment seems to affect the tree distribution in paddy fields. For example, the availability of forest resources is likely to influence how people manage trees within the paddy system (Grandstaff et al. 1986). However, there have been no systematic surveys to confirm the extent to which these various factors influence tree use and distribution in the paddy field land-use system in tropical Asia.

This study was therefore undertaken to better understand what factors determine tree distribution and species composition in paddy landscapes in central Laos. An examination of forest surrounding the villages was an important feature of the study for two reasons. Firstly, because paddy fields have been converted from forested land, so the trees present in the fields will exhibit some influence from the pre-existing forest (Watanabe et al. 1990). Inferences about changes in species composition with time require knowledge of the state at time zero as a reference. Secondly, people extract plant resources from both paddy fields and surrounding forests (Prachaiyo 2000), so the management of trees within the agricultural landscape is likely to be influenced by the abundance, proximity, and types of forest resources available.

The study examined the following three hypotheses:

(1) That species composition and distribution varies with micro and macro topography in paddy fields.
(2) That species composition and distribution changes over time after forest is converted to paddy field due to the change in environment.
(3) That as tree resources become increasingly scarce, local people respond by intensive tree management.

To test these hypotheses, we conducted field surveys of tree and species distribution, utilization, and management in three villages: a new village with adjacent forest, an old village with adjacent forest, and an old village without access to forest.

Site description and methods

Site description

The field survey was conducted at Dongmakngeo village (16°49′ N, 104°54′ E, 180 m a.s.l.: DM village), Outhomphone District, Bak village (16°27′ N, 105°09′ E, 160 m a.s.l.: BK village) and Nakhou village (16°29′ N, 105°09′ E, 140 m a.s.l.: NK village), Champhone District in Savannakhet Province, Laos (Figure 1). Savannakhet Province is located in central Laos, the mean annual temperature is 26.5 °C, the mean minimum and maximum temperatures are 21.6 and 31.3 °C respectively. The mean annual rainfall is 1473 mm, and the mean rainy season (May–October) and mean dry season (November–April) rainfalls are 1299.2 and 173.8 mm respectively. The original forest vegetation types of the study site are dry dipterocarp forest (DDF), dry evergreen forest (DEF), and mixed deciduous forest (MDF) on undulating terrain formed on Mesozoic red sandstone.

The characteristics of the selected three villages are listed in Table 1. Dongmakngeo village was

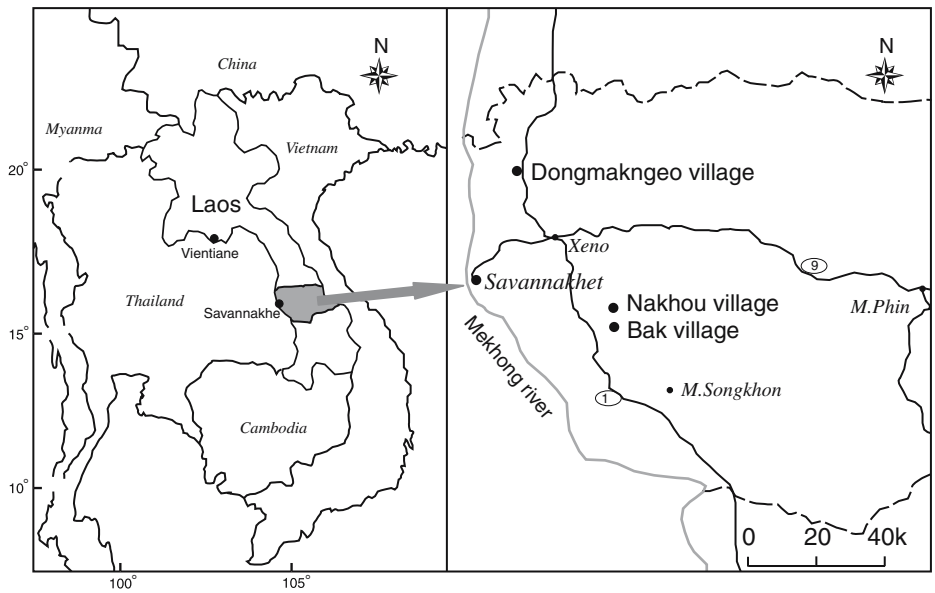

Figure 1. Map of study site in Savannakhet Province, Central Lao, PDR.

Table 1. Characteristics of the study site in Central Lao, PDR.

Vil	Year	Ethnic	Popul	House	Land	Forest	Subsistence
DM	44	LT	897	140	528	271	Paddy cultivation, Shifting cultivation, Cutting, NTFP collection
BK	> 200	LL	1852	327	1405	454	Paddy cultivation, Shifting cultivation, NTFP collection
NK	> 100	LL	1594	252	n/a	A few	Paddy cultivation, salt making, Mat weaving

Vil: village name, year: years after village establishment, ethnic: ethnic groups; LT: Lao theung people, LL: Lao lum people, Popul: population (people), House: number of households, Land: area of village land (ha), forest: area of forested land (ha), subsistence: main subsistence at village, NTFP: non-timber forest products.

established in 1960. At the time of the study it had a population of 897 people, mostly Lao-Theung people of the Austroasiatic ethnolinguistic family (Sisouphanthong and Taillard 2000), in 140 households. There were 271 ha of forest measured within the 528 ha of village land. Ninety percent of households were reported to engage in paddy cultivation and 10% in cutting trees. Small patches of shifting cultivation fields were observed within the forest areas. Bak village is said to have more than 200 years of history and had a population of 1852 people in 327 households during the study, mostly Lao-Lum people of the Tai-Kadai ethnolinguistic family (Sisouphanthong and Taillard 2000). There were 454 ha of forest recorded within the 1405 ha of village land. Ninety percent of households were engaged in paddy cultivation and about 10%, mainly older people, in shifting cultivation. Nakhou village is adjacent to Bak village and was established more than 100 years ago. Its population during the study was 1594, mostly Lao-Lum people, in 252 households. The village area had only several hectares of forest. All households were engaged in paddy cultivation. Pollarded trees were observed in paddy fields (Figure 2).

Analysis of aerial photographs showed that the land-use of all three villages could be mostly classified as forest, grassland, paddy fields, or homesteads. Three types of cropping pattern exist within the study area: (1) Rainy season crop only. Most paddy fields are rain-fed and are cultivated only in the rainy season. After rice harvesting, no crops are cultivated in paddy fields with the exception of some corn and sweet potatoes along riversides where water is available. (2) Second crop in the dry season. A few hectares of paddy fields in Bak village are irrigated with water from springs

Figure 2. Pollarding of *Peltophorum dasyrrhachis* for firewood collection at Nakhou village, Central Lao, PDR.

permitting a second crop in the dry season. This second cropping did not occur in Dongmakngeo village and Nakhou village. (3) Dry season crop only. In Nakhou village, some lowland paddy fields were flooded in the rainy season and could only be cultivated in the dry season when the water level fell.

Data collection

Field surveys were carried out in September and November 2001, May and June 2002, and March 2003. To assess tree distribution in paddy fields, plots were randomly set in fields of different age (years since conversion from forest) in each village: 1, 5, 10 and 30 years at Dongmakngeo village, 50 and 100 years at Bak village, and 10, 50 and 100 years at Nakhou village. The plots varied in area as they corresponded to the complete block of the respective paddy owner. Species name, habitat, DBH, and height of trees (>1 m in height; including shrubs and woody lianas) were recorded and specimens collected at each plot. Habitats of trees were classified into four types: paddy surface, paddy levees, termite mounds on paddy surface, and termite mounds on paddy levees. Species names of seedlings (young individuals without second order branching) and saplings (well established individuals with identifiable crown due to emergence of second and third order branches) were also recorded when observed in the plots.

To examine the wider range of tree distribution, a belt-transect survey was conducted in Nakhou village. The transect was established in paddy fields along both sides of the village road (3 km long and 200 m wide), where 1971 trees were left. The preliminary field observation had shown that tree distribution in the paddy fields was not influenced by the presence of the village road. All tree measurements were the same as for the plot survey, except that the location of each tree was also recorded using GPS (Garmin GPS III Plus).

Vegetation survey was conducted to determine general floristic characteristics of surrounding forests. Plots (20 m square) were set within representative areas of DDF, DEF, MDF, *Peltophorum dasyrrhachis* dominant forest (PTF), swamp forest with *Syzygium* spp. (SWF), and gallery forest with *Dipterocarpus alatus* Roxb. ex G. Don along streams (GLF). Species name, DBH, and height of trees (>1.5 m in height or >3 cm DBH) were recorded at each plot. Species names of seedlings and saplings were also recorded when observed in the plots.

Interview surveys were performed to ascertain former vegetation, method of forest conversion into paddy fields, and the local name and use of

tree species. One key informant and several other persons engaged in agricultural activities in paddy fields were consulted at each village. In Nakhou village, 15 households were also interviewed about the use and management of trees in paddy fields in detail.

Data analysis

Density, basal area, number of species, percentage of the three dominant species, percentage of large trees (> 30 cm DBH), and mean DBH were calculated from the tree distribution data for paddy plots of different ages. Regeneration patterns (naturally regenerated, planted, or not regenerated) of tree species in forest habitat (forested land where human disturbance was not intensive), woods habitat (forested land where human disturbance was intensive), and village habitat (cultivated land, grassland, or homegarden) were estimated by field observation of seedlings and saplings. The probable agent of seed dispersal was determined on the basis of fruit types and available literature (Van der Pijl 1982; Gardner et al. 2000).

The data collected by GPS were analyzed with geographical information system software *ArcView* version 3.1 (ESRI), topographic maps (published in 1983), and aerial photographs (taken in December, 1997).

The collected plants were identified in the Faculty of Forestry, National University of Laos, Vientiane, Laos, and in The Forest Herbarium, Royal Forestry Department, Bangkok, Thailand (BKF). Nomenclature of sampled plant species followed Gardner et al. (2000), Ho (1999–2000), Santisuk and Larsen (1997–2002), and Smitinand and Larsen 1970–1996).

Results

Forest vegetation and conversion

When Dongmakngeo village was established in 1960, DEF covered the entire area. However, only half of the land is now covered by forest following conversion to paddy fields. The vegetation survey showed that three types of forest, DEF, DDF and MDF, extend over the lowland to upper land on undulating terrain of the village. Conversion had progressed upslope beginning in the lowland. More recently, DDF on the slightly higher land had been targeted. When the forest was cleared, trees were cut selectively in two ways. One method was cutting directly with ax and saw. The other was cutting after girthing, i.e., killing trees by removing a ring of bark and sapwood around the trunk. Normally, trees with a large straight trunk were left standing due to their timber value or labor requirement for removal.

Bak village was located on slopes with forest covering 32% of the land. Forests consisted of secondary forest dominated by *Dialium cochinchinensis* Pierre. and *Peltophorum dasyrrhachis* (PTF) on the upper slope, SWF surrounding water bodies on the foot slopes, and the village sacred forest with large trees of *Dipterocarpus alatus* and *Lagerstroemia* sp. (DEF) on the flood terrace. Paddy fields were mostly established more than 50 or 100 years ago on lower land facing SWF and DEF.

Aerial photography of Nakhou village showed that most of the land was covered by paddy fields. Older residents mentioned that there had been many stands of *Dipterocarpus alatus, Lagerstroemia* sp., and *Pterocarpus macrocarpus* around the village in the past, but few remained as a result of felling. Old paddy fields of more than 50 years were located on the lower land along streams in the east or around houses. On the other hand, new fields were established on the higher land in the west by clearing PTF. Remaining forested land was only small patches of PTF and GLF.

Species composition and distribution

A total of 137 woody species (including 17 shrubs and 7 woody lianas) were recorded in paddy fields at the three villages.

Figure 3 shows the characteristics of tree distribution in paddy fields of different ages. The results for Dongmakngeo village show lower tree density after conversion, but only minor change in basal area, implying that trees with large trunks have been preferentially left. The dominant species in each plot were *Dipterocarpus tuberculatus* Roxb., *Shorea obtusa* Wall. ex Blume, and *Terminalia alata* Heyne ex Roth, the indicator species of DDF. Although 12 species were recorded in 1-year paddy fields, only the three dominant

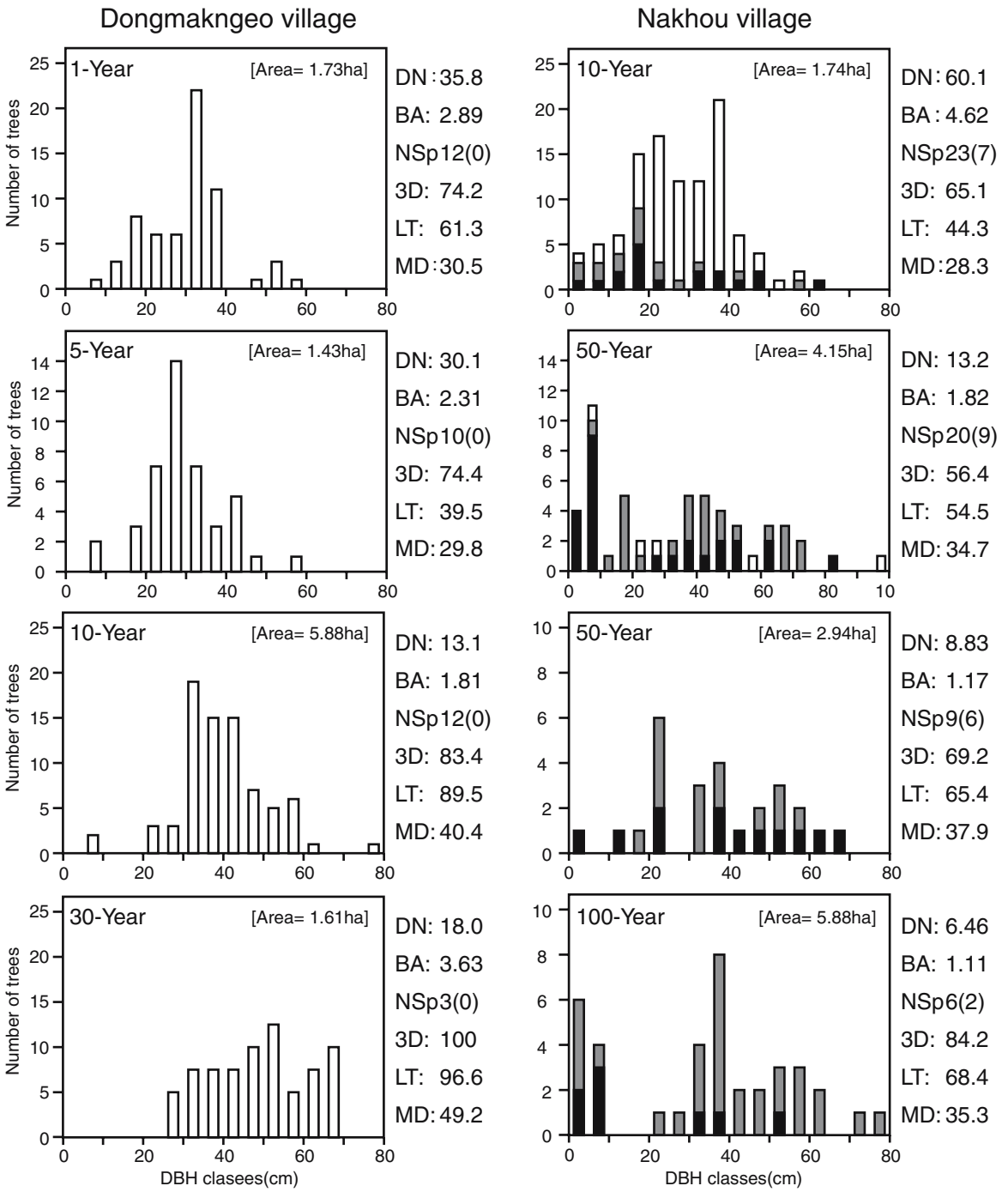

Figure 3. Distribution of DBH classes for trees in paddy fields at Dongmakngeo village and Nakhou village, Central Lao, PDR. White bars indicate remnant species, gray bars ruderal species, and black bars planted species. DN: Density (ind./ha), BA: Basal area (m^2/ha), NSp: Number of species (number of planted species), 3D: Percentage of three dominant species, LT: Percentage of large trees (> 30 cm DBH), MD: Mean DBH (cm).

species existed in 30-year fields. The percentage of the three dominant species, percentage of large trees (>30cm DBH) and mean DBH increased in the older fields. There were 23 tree species observed in paddy fields at Dongmakngeo village (Appendix A). Among them, 20 were common DDF species. Of the other three species, only a few individuals existed, and these had all been planted. No species were found to regenerate in the paddy areas.

In Bak village, there were no trees in paddy fields, but a few individuals of *Syzygium gratum* (Wt.) S.N. Mitra var. *gratum* and *Lepisanthes rubiginosa* (Roxb.) Leenh. occurred on termite mounds. In addition, one shrub, *Melastoma saigonese* (Kuntze) Merr., grew in rows along some paddy levees. In grassland around paddy fields, *Crateva adansonii* DC., *Pandanus* sp., *Tamarindus indica* L., and some large stumps of *Dipterocarpus alatus* were scattered. Interview survey showed that trees that had formerly existed in paddy fields had since been felled.

In Nakhou village, it was notable that although tree density decreased, some trees still remained in older fields (Figure 3). Two study plots were used to characterize 50-year paddy field at Nakhou village because species composition differed considerably. The dominant species of each plot differed considerably as follows: *Peltophorum dasyrrhachis, Morinda tomentosa* Heyne, and *Leucaena leucocephala* (Lam.) de Wit in the 10-year field, *Streblus asper, Borassus flabellifer* L., *Ceiba pentandra* (L.) Gaertn in one of the 50-year fields, *Azadirachta indica* var. *siamensis, Tamarindus indica*, and *Streblus asper* in the other 50-year field, and *Mitragyna rotundifolia* (Roxb.) O.Ktze., *Ceiba pentandra*, *Streblus asper* in the 100-year field. The number of species in each plot was 23, 20, 9 and 6 species respectively, of which 7, 9, 6 and 2 species respectively were planted. The number of individuals was much greater than in Dongmakngeo village. The percentage of the three dominant species and percentage of large trees (> 30 cm DBH) increased in older fields. However, mean DBH did not change owing to the recruitment by regeneration and planting.

The typical distribution pattern of six major species in the belt-transect at Nakhou village was as follows: *Irvingia malayana* and *Peltophorum dasyrrhachis* tended to occur in clusters on higher land in the west. Although *Mitragyna rotundifolia* was widespread, it formed pure stands on lowland along streams in the east. *Streblus asper*, *Azadirachta indica* var. *siamensis*, and *Diospyros mollis* were widespread in older fields.

Figure 4 shows the distribution of trees by micro-topographic element in paddy fields for the 20 most common species at Nakhou village. It indicates that species composing pure stands, such as *Irvingia malayana*, *Peltophorum dasyrrhachis* and *Mitragyna rotundifolia*, tended to occur on paddy surface or on paddy levees. On the other hand, species distributed widely within older fields, such as *Streblus asper*, *Azadirachta indica* var. *siamensis*, and *Diospyros mollis*, tended to be on termite mounds. Planted species were found only in rather old paddy fields. Their distribution was primarily determined by micro-topography. Considering the fact that *Jatropha curcas* L. was planted only on paddy levees to form live fences, or that villagers took the trouble to broaden paddy levees to plant *Ceiba pentandra*, the distribution of these species was highly dependent on the intentions of paddy owners.

There were 119 tree species observed at Nakhou village, including 27 planted species (Appendix A). Among them, 25 species were found to regenerate in paddy area. It should be noted that species composing pure stands on paddy surface had few saplings in paddy area, whereas species scattered on termite mounds were regenerating (Figure 5). As to the 27 planted species, the most common ones were *Leucaena leucocephala*, *Tamarindus indica*, *Annona squamosa* L. and *Borassus flabellifer*. They included naturally growing species, such as *Millingtonia hortensis* L.f., which was sometimes planted as a medicinal or ornamental tree. Although most planted species were protected from livestock grazing when they were small, seedlings and saplings of *Leucaena leucocephala* and *Borassus flabellifer* seemed to grow naturally as an escaped plant.

Human use and management

Trees in paddy fields were found to supply various kinds of products in Dongmakngeo village. Trunks of the most abundant species, *Dipterocarpus tuberculatus* and *Shorea obtusa*, are large and straight with high timber value. Oleoresin (Ankarfjard and Kegl 1998) collected from *Dipterocarpus* spp., called *namman nyang*, is used for fuel in traditional

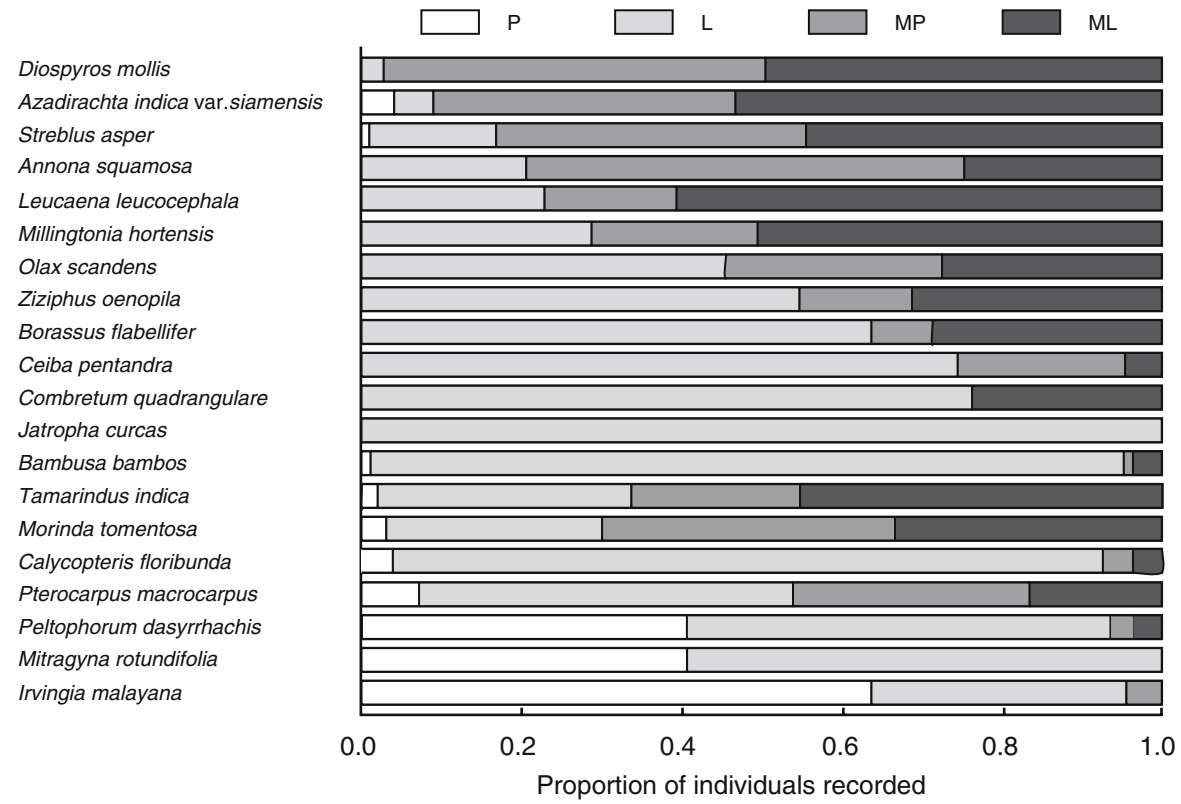

Figure 4. Distribution of trees by micro-topographic element in paddy fields in Nakhou Village, Central Lao, PDR. Data show the proportion of all individuals occurring on paddy surface (P), paddy levees (L), termite mounds on paddy surface (MP), and termite mounds on paddy levees (ML).

torches. Resin from *Shorea* spp., called *khi sii*, is used in coating handmade water containers. Both are not only self-consumed, but are a source of income that compensates for shortages in rice yield. Charcoal making is conducted in the dry season when there is no farm work. Charcoal is made from *Dipterocarpus tuberculatus*, *Dipterocarpus obtusifolius*, *Terminalia alata*, and *Terminalia mucronata* Craib & Hutch. Fruits of *Schleichera oleosa* (Lour.) Oken, *Syzygium* spp., *Dillenia ovata* Wall. ex Hk.f. & Th., *Phyllanthus embrica* L. and seeds of *Parinari anamense* Hance, leaves of *Syzygium gratum* var. *gratum* and *Lophopetalum wallichii* Kurz are edible. The fruit of *Schleichera oleosa* is especially popular for its sour taste and forms an income source when in season. Among planted species, *Oroxylum indicum* (L.) Kurz produces edible fruits and flowers. Cotton-like aril of *Ceiba pentandra* is used for stuffing pillows or mattresses. The fruit of *Tamarindus indica* is one of the most popular foods and seasonings in the country. In addition, villagers were found to recognize the fallen leaves of *Telminalia alata, Shorea* spp., *Morinda tomentosa* and *Syzygium* sp. as good fertilizer for paddy soil. To the contrary, *Dipterocarpus tuberculatus* leaves are not used as such owing to their resistance to decomposition. Interviews with several paddy owners showed that despite their recognition of trees in paddy fields as useful resources, trees had been felled since conversion and are rarely protected.

In Bak village, although the fruit and young leaves of *Syzygium gratum* var. *gratum*, and fruit of *Lepisanthes rubiginosa* are popular foods, they are collected in forest, where they are more abundant. Fruits of *Tamarindus indica* are also essential and are collected mostly in home gardens for the same reason.

In Nakhou village, trees were found to supply food, charcoal and firewood, fodder, and materials for handicrafts rather than timber owing to their small and crooked trunks. For example, leaves and

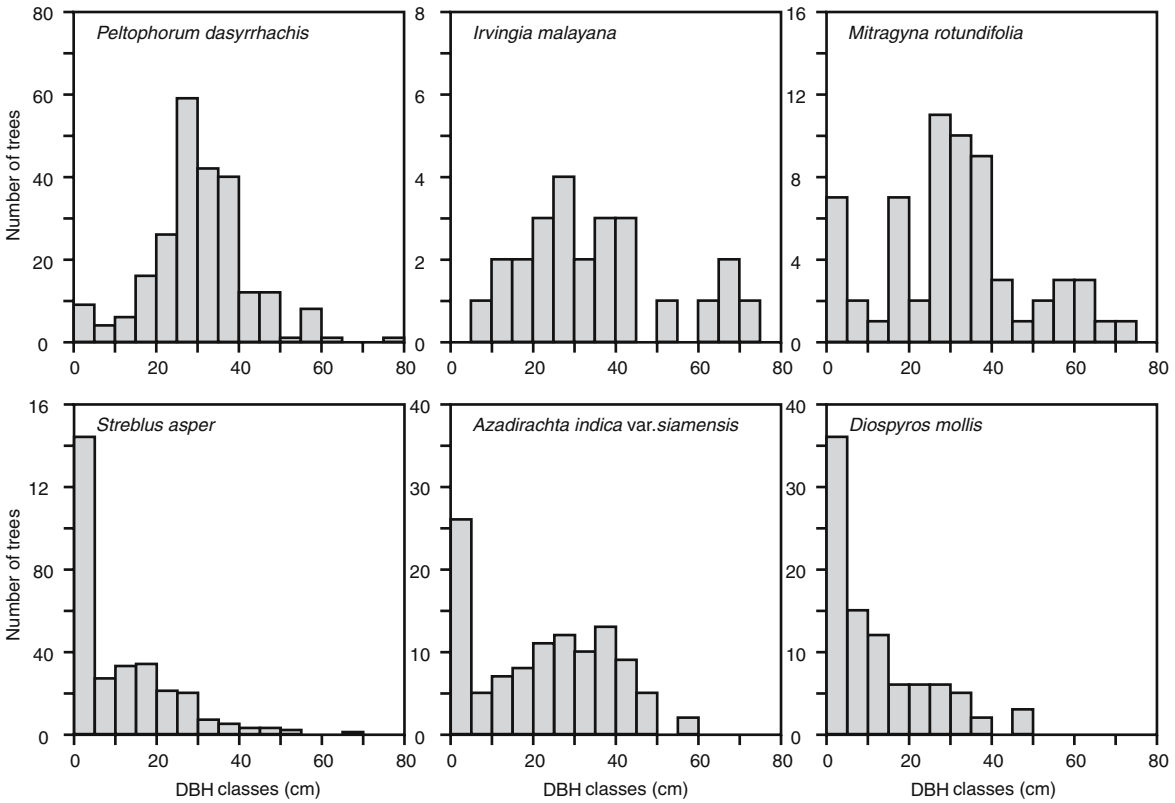

Figure 5. Distribution of DBH classes for six major species in paddy fields at Nakhou village, Central Lao, PDR.

flower buds of *Azadirachta indica* var. *siamensis*, *Bambusa bambos* (L.) Voss shoots, fruits and young shoots of *Leucaena leucocephala*, and seeds of *Irvingia malayana* are important foods. *Annona squamosa*, *Borassus flabellifer*, *Tamarindus indica*, and *Ziziphus mauritiana* Lam. are popular planted fruit trees. Although many species were found to be used for charcoal or firewood, *Irvingia malayana* yields the best quality charcoal. *Streblus asper* and *Samanea saman* (Jacq.) Merr. are used as fodder. *Ceiba pentandra* was preferably planted for cotton-like aril, which is an income source for the villagers. Villagers recognize the fallen leaves of *Peltophorum dasyrrhachis, Mitragyna rotundifolia, Memecylon* spp.,*Samanea saman*, and *Senna siamea* (Lmk.) Irwin & Barn. as good fertilizer for paddy soil. *Jatropha curcas* is planted as a live fence as it is not palatable to buffaloes and cattle. Apart from the direct uses shown in the Appendix A, almost all species mentioned by villagers provide a pleasant shade for both human and livestock and protect rice plants from strong sunshine. Interviews with 15 households showed reluctance of villagers to cut trees in the paddy fields because of their usefulness, except in newly established fields where the tree density is too high.

Impact of forest resources availability

Figure 6 indicates the tree density in paddy fields of different ages in the three villages. Trees were still standing in newly established paddy fields in Dongmakngeo village. In fact, because of the time and labor required, villagers often mentioned that tree cutting was not worth the trouble compared with rice cultivation. The number of planted species was quite small in contrast to the high tree density in the paddy fields. Instead, various kinds of forest products were collected in the surrounding forest and, as a result, the villagers were not concerned about the trees in the paddy fields.

At Bak village there were few trees in the paddy fields because their presence was not needed after conversion. The large area of surrounding forest provided ample firewood and timber for daily use.

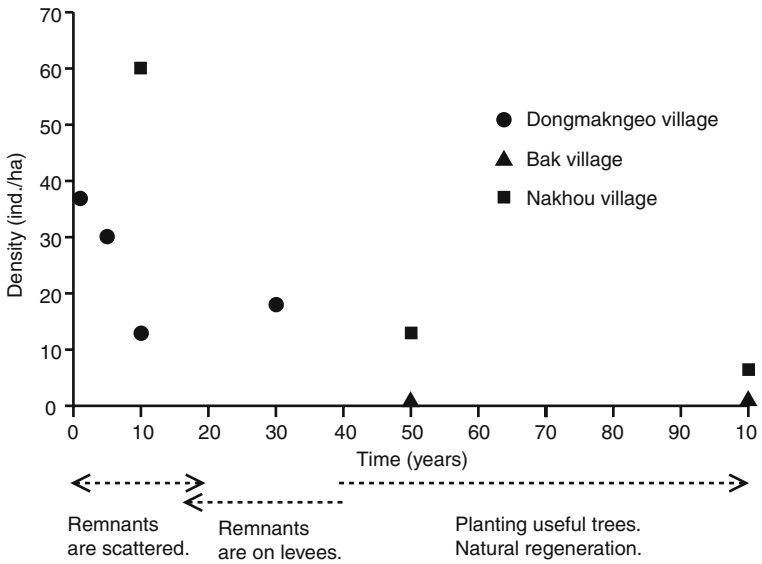

Figure 6. Tree density in paddy fields of different ages at the three villages, Central Lao, PDR.

On the other hand, people in Nakhou village buy firewood or charcoal from nearby villages owing to the scarcity of forested land. However, they were found to make the most of trees in paddy fields. In particular, the branches of *Peltophorum dasyrrhachis* and *Miragyna rotundifolia* are recognized as being quick to regenerate and are pollarded for firewood collection at a height of 2–3 m every 2 years (Figure 2). Figure 7 shows the effect of human management on tree growth. *Dipterocarpus tuberculatus* showed no significant difference in DBH-height ratio between paddy field and forest. On the other hand, *Peltophorum dasyrrhachis* in paddy field had shorter and thicker trunks than in shifting cultivation field, obviously due to pollarding.

Discussion

According to studies on trees in paddy fields in northeast Thailand, Grandstaff et al. (1986) recorded 54 species (including shrubs), Watanabe et al. (1990) recorded 17 species with a density of 30–148.7 ind./ha, and Prachaiyo (2000) recorded 28 species with a density of 14.9 ind./ha. Despite the difficulty in making comparisons with these studies due to differences in various conditions of the study plots, we recorded a high diversity of woody species.

However, this species diversity may decrease in the future. Of the 137 woody species in our study sites, only 47 were naturally regenerated or planted (Appendix A). Human interference and livestock grazing around paddy fields appears to induce high seedling mortality, as Hocking and Islam (1995) pointed out. It is important to note that the customs of the local people determined whether a species was naturally regenerated or planted. Several natural occurring species in this study site, such as *Azadirachta indica* var. *siamensis*, *Bambusa bambos*, *Combretum quadrangulare* Kurz, *Spondias pinnata* (L.f.) Kurz and *Sreblus asper*, are planted in northeast Thailand (Grandstaff et al. 1986). This means that the presence of trees in paddy fields was much influenced by people's management.

The results at Nakhou village implied that the range of tree species in paddy fields changed from one of predominantly forest vegetation to ruderal vegetation as time passed. Seedlings could not survive such a highly disturbed setting as paddy surface, thus pure stands of species such as *Irvingia malayana*, *Peltophorum dasyrrhachis* and *Mitragyna rotundifolia* on paddy surfaces (Figure 4) would be remnants of the original forest. Except for *Mitragyna rotundifolia*, these species had few saplings in the paddy area, so the number of individuals will decrease (Figure 5). Although many seedlings of remnant species, e.g.,

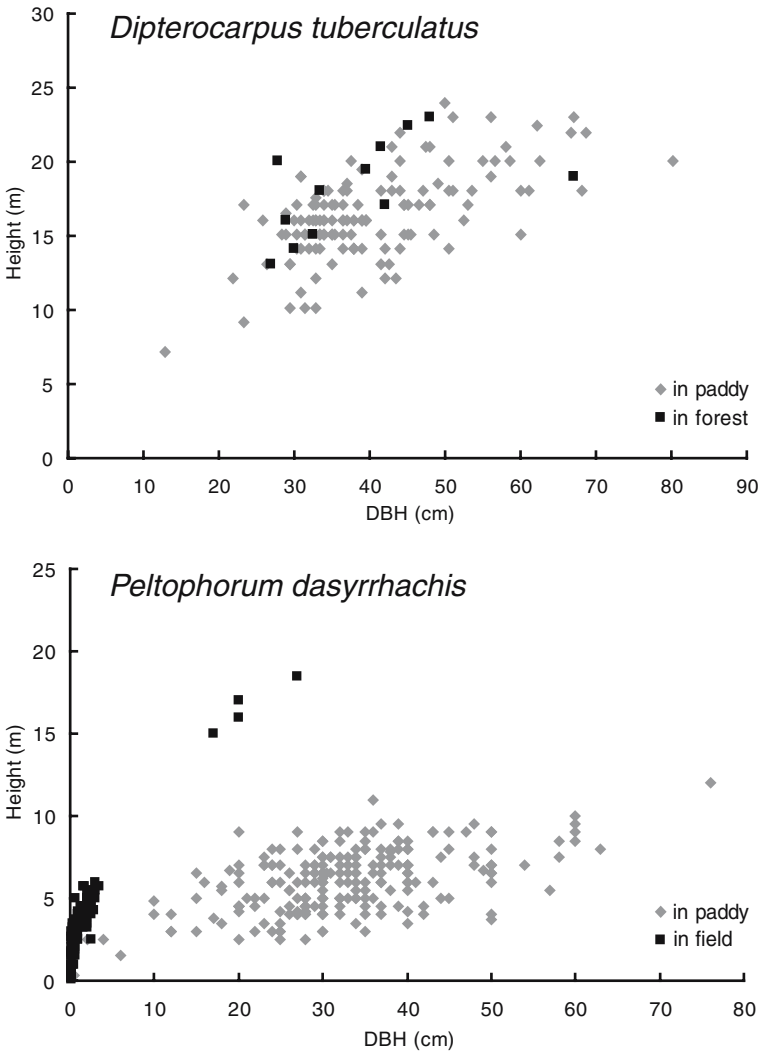

Figure 7. DBH and height for *Dipterocarpus tuberculatus* in paddy field (n = 133) and DDF (n = 13) at Dongmakngeo village and for *Peltophorum dasyrrhachis* in paddy field (n = 225) at Nakhou village and shifting cultivation fields (n = 113) at Bak village, Central Lao, PDR.

Peltophorum dasyrrhachis, were observed on paddy levees at the beginning of the rainy season, none survived to become saplings. The only exception was a pure stand of *Mitragyna rotundifolia*, including saplings, which occurred in frequently flooded low-lying fields. This species adapted to a disturbed area where other species could not grow. The probable decline in remnant species in agricultural landscapes has also been reported for trees in pasture (Harvey and Haber 1999), where no regeneration occurred in the study site from trees retained from the primary forest. On the other hand, species scattered on termite mounds in older paddy fields (Figure 4), such as *Streblus asper*, *Azadirachta indica* var. *siamensis*, and *Diospyros mollis*, were rarely found in surrounding woods, but occurred in paddy areas. This indicates that they were ruderal species (Grime 2001) adapted to the disturbed paddy field environment and seeming to increase in number. Their probable mode of dispersal (Van der Pijl 1982) is by birds and bats (Appendix A).

Some additional uses of the common species recorded in northeast Thailand (Grandstaff et al. 1986) include: sugar making from *Borassus flabellifer;* cultivating valuable edible fungus with *Ceiba pentandra*; and producing red dye and lac from insects on *Samanea saman*. Some of these

Table 2. Summary of forest resources availability at the three villages, Central Lao, PDR.

	Forest		Paddy fields	
DM	○	DDF: timber, firewood, resin, food, medicine were collected, MDF: timber, food, medicine were collected, DEF: village sacred forest. Food and resin were collected	○	Trees were left standing in the young paddy fields, though villagers were not consciously observing any tree protection requirements, The trees provided timber, resin, charcoal, and food
BK	○	PTF: timber, firewood, food and other NTFPs were collected, SWF: village protected forest, food was collected, DEF: village sacred forest, food was collected	×	Trees were absent owing to previous cutting, villagers with access to rich resources in adjacent forest had no need for plantings on paddy levees
NK	Δ	PTF: a little food was collected, GLF: a little food was collected	Δ	Trees were intentionally left in paddy fields as supplementary source for daily use. They provided food, charcoal and firewood, fodder, and material for handicrafts

Firewood, food and timber were considered as the main forest resources for daily livelihood.
○: adequate supplies for daily use
Δ: insufficient. Supplementary source needed
×: absent

uses provide sources of cash income and seem to be important to rural development in the study site for the current study in Laos.

The relationship between humans and trees varied with the environmental conditions, such as forest resources availability (Table 2). Grandstaff et al. (1986) hypothesized that tree management in paddy fields gradually evolves from a state of high tree density with little human care to one of low tree density with intensive human intervention. The results of this study supported that hypothesis. At Nakou village, where forest resources were scarce, tree density was high in the newly established fields, and trees still remained in older fields (Figure 6). This fact reflected the villagers' care for trees in paddy fields. Paddy fields converted from original forest, therefore, play a similar role to forest in supplying resources (Grandstaff et al. 1986; Watanabe et al. 1990; Prachaiyo 2000). On this issue, further analysis over a wider area is important to consider both forest resources management and villagers' livelihood at the regional level.

Conclusion

Species composition and distribution of trees in paddy fields differed considerably between the three study sites owing to three factors: (1) micro and macro topography in paddy fields, (2) years since conversion from forest, and (3) forest resources availability. Remnant species dominant in newly established fields had been replaced with ruderal ones as time passed. Overall tree density depended on villagers' management practices, such as the rate of cutting trees and planting of useful trees. In addition, these management practices were influenced by forest resource availability in the village. The need for trees in paddy fields was greater in the village without forested land. Thus, paddy fields do not form a homogenous landscape, but embody various species compositions and tree distributions owing to micro and macro topography under human management.

In Laos, inventories in 1982 and 1989 showed that deforestation was occurring at 70,000 ha per year, mainly due to shifting cultivation, logging, and collection of firewood (NOFIP 1992). Although the forest law that became effective in 1996 placed restrictions on logging and shifting cultivation to some extent, 97% of the households in the country still use wood or charcoal for cooking fuel (LWU 2001). Wood consumption is estimated to be 1 cubic meter/person/year (LWU 2001). Our study shows that the interaction between humans and trees occurs continuously through a process where forest is progressively transformed into cultivated land. The farmer-paddy field system may be important for reestablishing efficient resource use in the country if the people begin to manage trees in the rice fields for their own use (Prachaiyo 2000). In other words, it is possible that small-scale tree management by villagers, which is not revealed in national forestry statistics, could contribute to relieving deforestation at the national level.

Appendix A. Tree species recorded at paddy fields in Dongmakngeo village and Nakhou village, Central Lao, PDR.

No.	Species	Family	Local name	T. no.	Forest-habitat	Village-habitat	Species type	Probable dispersal agent	Use
Dongmakngeo village									
1	*Dipterocarpus tuberculatus* Roxb.	Dip	Mai Kun	138	N		Remnant	Wind	T, R, C, O
2	*Shorea obtusa* Wall. ex Blume	Dip	Kok Chik	48	N		Remnant	Wind	T, R, S
3	*Terminalia alata* Heyne ex Roth	Com	Kok Seuak	45	N		Remnant	Wind	S, C, T, M
4	*Aporosa villosa* Baill.	Eup	Kok Meuat	6	N		Remnant	n/a	M
5	*Mitragyna rotundifolia* (Roxb.) O.Ktze.	Rub	Kok Thom	6	N		Remnant	Water?	T
6	*Morinda tomentosa* Heyne	Rub	Kok Nyo	5	N		Remnant	Bats	M, S
7	*Syzygium* sp.	Myr	Kok Waa	5	N		Remnant	Birds	Fo, S
8	*Terminalia mucronata* Craib & Hutch.	Com	Mai Peuay leuat	5	N		Remnant	Wind	C
9	*Parinari anamensis* Hance	Ros	Mai Phok	3	N		Remnant	n/a	Fo
10	*Shorea siamensis* Miq.	Dip	Mai Hang	3	N		Remnant	Wind	T, R, S
11	*Dillenia ovata* Wall. ex Hk.f. & Th.	Dil	Kok Saan	2	N		Remnant	Birds	Fo
12	*Gluta usitata* (Wall.) Ding Hou	Ana	Kok Nam kiang	2	N		Remnant	Wind	
13	*Strychnos nux-blanda* A.W.Hill	Log	Kok Tum kaa	2	N		Remnant	n/a	M
14	*Terminalia chebula* Retz.	Com	Kok Sommo	2	N		Remnant	Birds	
15	*Dalbergia* sp.	Leg	Mai Padong	1	N		Remnant	Ruminants	T
16	*Dipterocarpus obtusifolius* Teysm. ex Miq.	Dip	Mai Saat	1	N		Remnant	Wind	T, R, C, O
17	*Lophopetalum wallichii* Kurz.	Cel	Kok Sii khok	1	N		Remnant	Wind	Fo
18	*Phyllanthus embrica* L.	Eup	Kok Kham phon	1	N		Remnant	Birds	Fo
19	*Schleichera oleosa* (Lour.) Oken	Sap	Kok Khosom	1	N		Remnant	Birds	Fo
20	*Syzygium gratum* (Wt.) S.N.Mitra var. *gratum*	Myr	Kok Samek	1	N		Remnant	Birds	Fo
21	*Oroxylum indicum* (L.) Kurz	Big	Kok Linmai	n/a		P	Planted	Human	Fo
22	*Ceiba pentandra* (L.) Gaertn	Bom	Kok Niu	n/a		P	Planted	Human	H
23	*Tamarindus indica* L.	Leg	Kok Kham	n/a		P/N?	Planted	Human	Fo
Nakhou village									
No.	Species	Family	Local name	T.no.	Woods-habitat	Village-habitat	Species type	Probable dispersal agent	Use
1	*Streblus asper* Lour.	Mor	Kok Sompho	301	N	N	Ruderal	Birds	Fr, Fd, M, Fo, O
2	*Peltophorum dasyrrhachis* (Miq.) Kurz	Leg	Kok Sa fang	248	N	(N)	Remnant	Ruminants	T, C, Fr, S
3	*Calycopteris floribunda* (Roxb.) Lamk.	Comb	Kheua Kaden	116	N	N	Ruderal	Wind	Fr, O
4	*Azadirachta indica* A.Juss. var. *siamensis* Valeton	Meli	Kok Ka dao	108	N	N	Ruderal	Bats	Fo, T, M
5	*Diospyros mollis* Griff	Ebe	Kok Keua	81	N	N	Ruderal	Birds	Fr, Fo, (H)
6	*Bambusa bambos* (L.) Voss	Gra	Mai Phai paa	80	N	N	Ruderal		Fo, H
7	*Mitragyna rotundifolia* (Roxb.) O.Ktze	Rub	Kok Thom	66	N	N	Remnant/ruderal	Water?	C, T, S
8	*Leucaena leucocephala* (Lam.) de Wit	Leg	Kok Ka thin	47		P/N	Planted	Human, Ruminants	Fo, C
9	*Tamarindus indica* L.	Leg	Kok Kham	47		P/(N)	Planted	Human, Ruminants	Fo
10	*Pterocarpus macrocarpus* Kurz	Leg	Mai Dou	41	N		Remnant	Wind	T
11	*Annona squamosa* L.	Ann	Kok Khiap	41		P	Planted	Human	Fo
12	*Olax scandens* Roxb.	Ola	Ton Nyo ngua	37	N	N	Ruderal	Birds	Fo
13	*Borassus flabellifer* L.	Pal	Kok Tan	36		P/N	Planted	Human, Ruminants?	Fo, T, O

Appendix A. Continued.

No.	Species	Family	Local name	T. no.	Forest-habitat	Village-habitat	Species type	Probable dispersal agent	Use
14	*Morinda tomentosa* Heyne	Rub	Kok Nyo	30	N		Remnant	Bats	Fr
15	*Millingtonia hortensis* L.f.	Big	Kok Khankhon	28	N	P/N	Ruderal/ Planted	Wind	M, O
16	*Ceiba pentandra* (L.) Gaertn	Bom	Kok Niu	28		P/(N)	Planted	Human	H
17	*Combretum quadrangulare* Kurz	Comb	Kok Kee	26	N	N	Ruderal	Water	Fr, O
18	*Irvingia malayana* Oliver ex A.Benn.	Irv	Mai Bok	25	N		Remnant	Ruminants	C, Fo
19	*Jatropha curcas* L.	Eup	Mak Nyao	23		P	Planted	Human	O
20	*Ziziphus oenopila* (L.) Mill.	Rha	Nam Lep meo	22	N	N	Ruderal	Birds	O
21	*Feronia* sp.	Rut	Kok San	20	N	N	Ruderal	n/a	T, C, Fo
22	*Ziziphus mauritiana* Lam.	Rha	Kok Ka than	20		P/N	Planted	Birds	Fo
23	*Maytenus marcanii* Ding Hou	Cel	Kok Ben	19	N	N	Ruderal	n/a	Fo
24	*Cassia fistula* L.	Leg	Mai Khoun	19		P/N	Planted	Human	T, O
25	*Salacia chinensis* L.	Cel	Kok Ta kai	19	N		Remnant	Birds	Fr, M
26	*Albizia lebbekoides* Benth.	Leg	Kok Khang houng	18	N		Remnant	Ruminants	T
27	*Naringi crenulata* (Roxb.) D.H.Nicolson	Rut	Kok Kasung	16	N	N	Ruderal	Birds	Fo
28	*Memecylon* sp.	Mela	Kok Meuat ee	16	N	(N)	Remnant	Birds	T, S
29	*Xylia xylocarpa* (Roxb.) Taub. var. *kerrii* (Craib & Hutch.) Nielsen	Leg	Mai Deen	15	N		Remnant	Ruminants?	T, Fo
30	*Acacia harmandiana* (Pierre) Gagnep.	Leg	Kok Phi man	14	N	N	Ruderal	Ruminants	Fr, M
31	*Dipterocarpus intricatus* Dyer	Dip	Mai Sa beng	14	N		Remnant	Wind	T
32	*Crateva adansonii* DC.	Cap	Kok Kam	13	N	(N)	Remnant	n/a	Fr
33	Bignoniaceae sp.	Big	Kok Mou	13	N		Remnant	Wind	Fr
34	*Mangifera indica* L.	Ana	Kok Mouang	13		P	Planted	Human	Fo
35	*Bambusa blumeana* Schult.f.	Gra	Mai Phai ban	13		P	Planted		Fo, T, H
36	Unidentified		Kok Khon tha	12	N		Remnant	n/a	M
37	*Psidium guajava* L.	Myr	Kok Sida	11		P	Planted	Human	Fo, M
38	*Samanea saman* (Jacq.) Merr.	Leg	Kok Samsa	11		P/(N)	Planted	Ruminants	Fd, Fr, C, S, O
39	*Haldina cordifolia* (Roxb.) C.E.Ridsdale	Rub	Kok Khao	10	N	N	Ruderal	n/a	Fr
40	*Ziziphus cambodiana* Pierre	Rha	Nam Khom	9	N		Remnant	Birds	
41	*Cananga latifolia* (Hk.f. & Th.) Fin. & Gagnep.	Ann	Kok Thong nao	9	N	(N)	Remnant	Birds	T, Fr
42	*Syzygium* sp.	Myr	Kok Waa	9	N	N	Ruderal	Birds	C, Fo, T
43	*Randia* sp.	Rub	Nam Nian paduk	8	N		Remnant	Birds	
44	*Terminalia alata* Heyne ex Roth	Comb	Kok Seuak	8	N		Remnant	Wind	T
45	*Cratoxylum* sp.	Hyp	Kok Tiu	8	N	N	Ruderal	n/a	Fo
46	*Carica papaya* L.	Car	Kok Houng	8		P	Planted	Human	Fo
47	*Eucalyptus* sp.	Myr	Mai Vik	8		P	Planted	Human	O
48	*Acacia* sp.	Leg	Kheua Kachay	7	N		Remnant	Ruminants	
49	*Capparis flavicans* Kurz	Cap	Kok Namten	7	N	N	Ruderal	n/a	
50	*Careya arborea* Roxb.	Lec	Kok Kadon	6	N		Remnant	n/a	Fo, M, O

51	*Diospyros montana* Roxb.	Ebe	Kok Keua kaa	6	N	N	Ruderal	Birds	
52	*Bombax anceps* Pierre	Bom	Kok Niupaa	6	N		Remnant	Wind	
53	*Phyllanthus taxodiifolius* Beille	Eup	Kok Siao	6	N	N	Ruderal	Birds	Fr, S
54	*Cocos nucifera* L.	Pal	Kok Phao	6		P	Planted	Human	Fo, H
55	*Terminalia bellirica* Roxb.	Com	Kok Heen	5	N		Remnant	Birds	T
56	Unidentified		Mai Sa khon don	5	N		Remnant	n/a	Fr
57	*Oxyceros horridus* Lour.	Rub	Kok Khankhao	4	N	N	Ruderal	Birds	M
58	*Memecylon* sp.	Mel	Kok Meuat nyai	4	N		Remnant	Birds	T, S
59	*Casearia grewiaefolia* Vent.	Fla	Kok Paa sam	4	N	(N)	Remnant	n/a	M
60	Combretaceae sp.	Com	Ton Sak paa	4	N		Remnant	n/a	
61	*Plumeria obtusa* L.	Apo	Kok Cham paa	4		P	Planted	Human	O
62	*Delonix regia* (Boj. ex Hook.) Raf.	Leg	Kok Fang nyung	4		P	Planted	Human	Fo, O
63	*Bambusa* sp.	Gra	Mai San phai	4		P	Planted		Fo, T, H
64	*Sennna siamea* (Lmk.) Irwin & Barn.	Leg	Kok Khi lek	3		P/N	Ruderal /Planted	Ruminants	Fo,Fd,Fr,S,O
65	*Lepisanthes rubiginosa* (Roxb.) Leenh.	Sap	Mak Houat	3	N	(N)	Remnant	Birds	Fo
66	*Breynia glauca* Craib.	Eup	Kok Khomma	3	N		Remnant	n/a	
67	*Sindora siamesis* Teysm. ex Miq. var. *siamensis*	Leg	Kok Tee nam	3	N		Remnant	Rodents?	T
68	*Holarrhena curtisii* King & Gamble	Apo	Kok Muk	2	N		Remnant	Wind	
69	*Shorea siamensis* Miq.	Dip	Mai Hang	2	N		Remnant	Wind	T
70	*Lagerstroemia macrocarpa* Kurz var. *macrocarpa*	Lyt	Kok Kakalao	2	N	P	Remnant/ planted	n/a	Fr
71	*Dalbergia* sp.	Leg	Mai Ka nyung	2	N		Remnant	Ruminants	T
72	Unidentified		Kheua Tumkaa	2	N		Remnant	n/a	
73	*Spondias pinnata* (L.f.) Kurz	Ana	Mak Kok	2	N		Remnant	Bats?	Fo
74	*Glochidion* sp.?	Eup	Mak Duk	2	N		Remnant	n/a	Fo
75	*Gluta usitata* (Wall.) Ding Hou	Ana	Kok Nam kiang	2	N		Remnant	Wind	
76	*Ficus* sp.	Mor	Kok Pho	2	N		Remnant	Birds	
77	*Polyalthia* sp.	Ann	Kok Phi phouan	2	N		Remnant	Birds	Fo
78	*Cratoxylum* sp.	Hyp	Kok Tiu paa	2	N		Remnant	n/a	
79	*Catunaregam tomentosa* (Bl. ex DC.) D. D. Tirvengadum	Rub	Kok Nam theng	2	N		Remnant	n/a	
80	*Croton roxburghii* N.P.Balakr	Eup	Kok Pao	2	N		Remnant	n/a	
81	*Crescentia cujete* L.	Big	Kok Namtao	2		P	Planted	Human	H
82	*Morus macroura* Miq.	Mor	Kok Mon	2	N		Remnant	Birds	Fo, O
83	*Butea monosperma* (Lmk.) Taub.	Leg	Kok Chan	1	N		Remnant	Ruminants	
84	*Artocarpus lakoocha* Roxb.	Mor	Mai Haat	1	N		Remnant	Bats	Fo
85	*Ficus* sp.	Mor	Kok Hai	1	N		Remnant	Birds	Fo
86	Unidentified	Leg	Kok Iram	1	N		Remnant	n/a	
87	*Stereospermum* sp.	Big	Mai Kenpoi	1	N		Remnant	Wind	
88	Unidentified		Kheua Maktee	1	N		Remnant	n/a	
89	*Trachelospermum asiaticum* (Sieb. & Zucc.) Nakai	Apo	Kheua Seut	1	N		Remnant	Wind	O
90	Sapindaceae sp.	Sap	Kok Kai lin	1	N		Remnant	n/a	Fo, M
91	*Suregada multiflora* (A.Juss.) Baill.	Eup	Kok La monpaa	1	N		Remnant	n/a	

Appendix A. Continued.

No.	Species	Family	Local name	T. no.	Forest-habitat	Village-habitat	Species type	Probable dispersal agent	Use
92	*Antidesma* sp.	Eup	Kok Makmao	1	N		Remnant	Birds	
93	Unidentified		Kok Thun	1	N		Remnant	n/a	
94	Unidentified		Kok Kout	1	N		Remnant	n/a	
95	Unidentified		Kok Lanpuk	1	N		Remnant	n/a	
96	*Ficus* sp.	Mor	Mai Haiheuan	1	N		Remnant	Birds	
97	Unidentified		Kok Mii	1	N		Remnant	n/a	
98	*Lagerstroemia* sp.	Lyt	Mai Peuay	1	N		Remnant	Wind	T
99	*Hura crepitans* L.	Eup	Kok Pho thalee	1	N		Remnant	n/a	Fr
100	*Sterculia pexa* Pierre	Ste	Kok Samhong	1	N		Remnant	n/a	T, M
101	*Derris* sp.	Leg	Kok Tampaa	1	N		Remnant	Ruminants	
102	*Syzygium* sp.	Myr	Kok Waanoi	1	N		Remnant	Birds	Fo
103	*Pedilanthus* sp.	Eup	Kok Chinai	1		P	Planted	Human	Fo
104	*Calotropis gigantea* (L.) R.Br. ex Ait.	Asc	Dok Hak	1		P	Planted	Human	O
105	*Phyllanthus acidus* (L.) Skeels	Eup	Mak Nyom	1		P	Planted	Human	Fo
106	Unidentified		Kok Seua	1	N		Remnant	n/a	
107	*Wrightia arborea* (Dennst.) Mabb.	Apo	Kok Muk nyai	n/a	N	(N)	Remnant	Wind	Fr
108	*Asparagus* sp.	Asp		n/a	N		Remnant	Birds	
109	*Terminalia glaucifolia* Craib	Com	Kok Heen	n/a	N		Remnant	Wind	Fr, T
110	*Cassia alata* L.	Leg	Kok Khi lekban	n/a		P	Planted	Human	M
111	*Dialium cochinchinense* Pierre	Leg	Mai Kheng	n/a	N		Remnant	Birds?	T, Fo
112	*Milletia* sp.	Leg	Kok Chak chan	n/a	N		Remnant	Ruminants	Fr, O
113	Leguminosae sp.	Leg	Ton Sa monphai	n/a		P	Planted	Human	M
114	*Urena lobata* L.	Mal		n/a	N	N?	–	n/a	
115	*Ficus* sp.	Mor	Kok Deua	n/a	N	N?	–	Birds	Fo
116	*Maclura* sp.	Mor		n/a	N	N?	–	Birds	
117	*Schleichera oleosa* (Lour.) Oken	Sap	Kok Kho som	n/a	N		Remnant	Birds	Fo
118	*Helicteres hirsuta* Lour.	Ste		n/a	N	N?	–	n/a	
119	*Helicteres lantana* (Teysm. & Binn.) Kurz	Ste		n/a	N	N?	–	n/a	

Of 23 species identified at Dongmakngeo village, three species were planted, no species were found to regenerate in the paddy areas.
Of 119 species identified at Nakhou village, 27 species were planted, 25 species were found to regenerate in the paddy areas.
T. no.: Number of individuals occurring in the study plot. "N/a" indicates the species observed out of the plot. *Forest-habitat*: Species predominantly found in forested land where human disturbance was not intensive. *Woods-habitat*: Species predominantly found in forested land where human disturbance was intensive. *Village-habitat*: Species predominantly found in open lands such as cultivated land, grassland, or homegarden. "N" indicates naturally regenerating species, "(N)" indicates species whose seedlings grew naturally but seemed to die before reaching sapling stage, "P" indicates planted species. *Species Type*: Each species were identified as remnant, ruderal, or planted, according to its regeneration habit. *Probable Dispersal Agent*: The probable agent of seed dispersal was determined on the basis of fruit types and available literature. "Ruminants" represent cattle and buffalos. *Use*: The use at each village (C: charcoal, Fd: fodder, Fo: food, Fr: firewood, H: material for handicraft, M: medicine, O: others, R: resin, S: soil improvement, T: timber).

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